AMCAD Engineering
Advanced Modeling for Computer-Aided Design

GaN HEMTS Device Modeling Using ASM Standard-Extraction Flow and Validation

Fréderique SIMBÉLIE & Zacharia OUARDIRHI

Helping our customers to design smart and safe communication systems !

APRIL 2ND 2019
www.amcad-engineering.com

EDICON 2019
Electronic Design Innovation Conference
电子设计创新大会

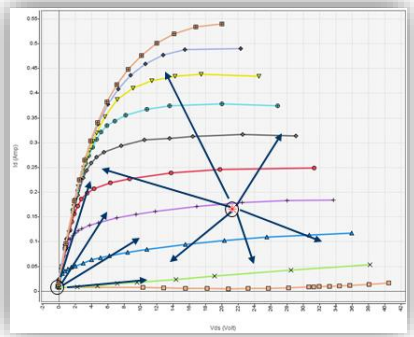
Outline

- **Hardware Requirements**
- **Model Extraction flow**
  - Small Signal FET modeling
  - Output Current Source
  - Diodes
  - Non-linear capacitances
  - Thermal & trapping effects
- **Large Signal Model Validation**

Hardware Requirements

Measurement System

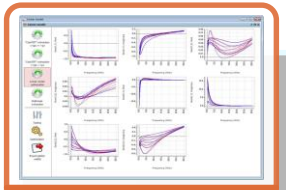
- Short pulse : Quasi-isothermal conditions
- Low duty cycle : Constant mean temperature
- Quiescent bias point :
  Thermal conditions fixed
  Traps conditions fixed



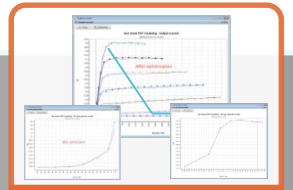
Advantages

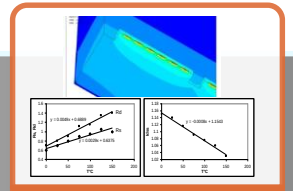
- ✓ High power dissipated areas // safe operating conditions
- ✓ Thermal effects : influence of QP on Idss
- ✓ Trapping effects (gate-lag & drain-lag)
- ✓ Precious modeling data inputs

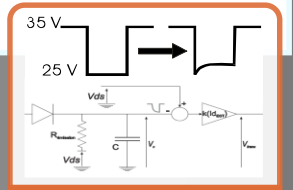
Model Extraction flow


Small-Signal


IV Model


Non-linear capacitances


Thermal model



Trapping effects

R_i
C_{ds}
τ
G_m
G_d
C_{gs}
C_{gd}
C_{ds}
R_{gd}

$I_{gs}=f(V_{gs},V_{ds})$

$I_{ds}=f(V_{gs},V_{ds})$

R_g
L_g
C_{pg}
L_s
C_{pd}
L_d
R_s
R_d

$C_{gs}=f(V_{gs})$
$C_{gd}=f(V_{gd})$
$C_{ds}=f(V_{ds})$

$I_g=f(V_{gs},T)$
$I_{ds}=f(V_{gs},V_{ds},T)$

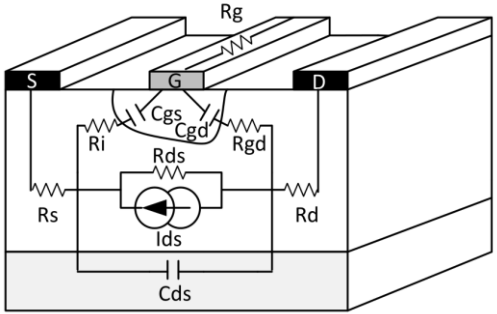
Opt1:
$C_{gs}=f(V_{gs},T)$
$C_{gd}=f(V_{gd},T)$
$C_{ds}=f(V_{ds},T)$

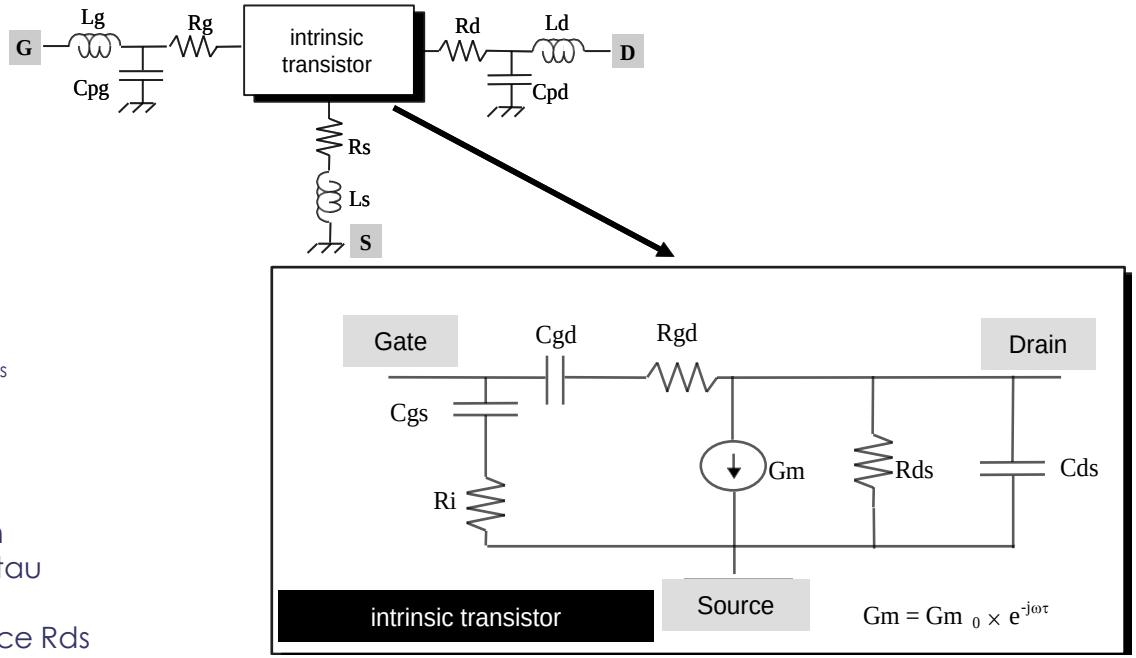
Opt2:
$I_{ds}=f(V_{gs\_trap},V_{ds\_trap},T)$

$R_s=f(T)$
$R_d=f(T)$

Various effects are successively added

Small Signal FET modeling





- **Extrinsic parameters**
  - pad capacitances C_{pg}, C_{pd}
  - port metallization inductances L_g, L_d, L_s
  - port ohmic résistances R_g, R_d, R_s
- **Instrinsic parameters**
  - channel capacitances C_{gs}, C_{gd}
  - voltage-controlled current source with transconductance gm and transit time delay tau
  - ohmic résistances R_i, R_{gd}
  - output capacitance Cds and resistance Rds

Small Signal FET modeling

• Extraction of extrinsic and intrinsic parameters:

Four steps

Step 1 (optional) - Extrinsic parameters initialization with cold FET measurements using foundry parameters : Rc

$$Z_{11} = Rg + Rs + \frac{Rc}{3} + \frac{n.k.T}{q.Ig} + j\omega.(Ls + Lg)$$

$$Z_{21} = Z_{12} = Rs + \frac{Rc}{2} + j.\omega.Ls$$

$$Z_{22} = Rd + Rs + Rc + j.\omega.(Ls + Ld)$$

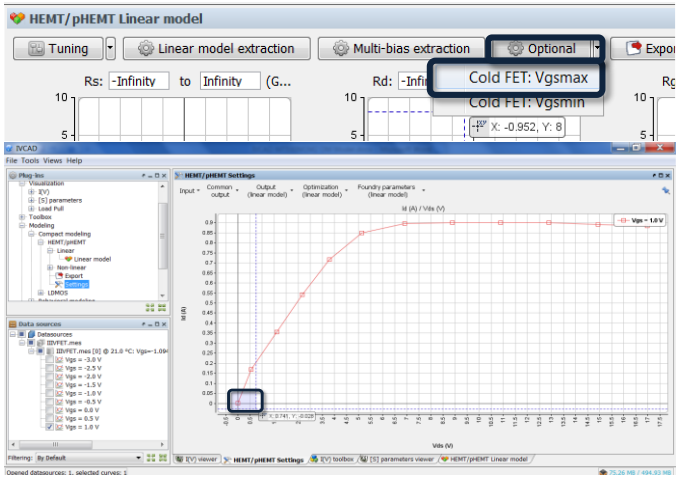
V_{ds} = 0 V

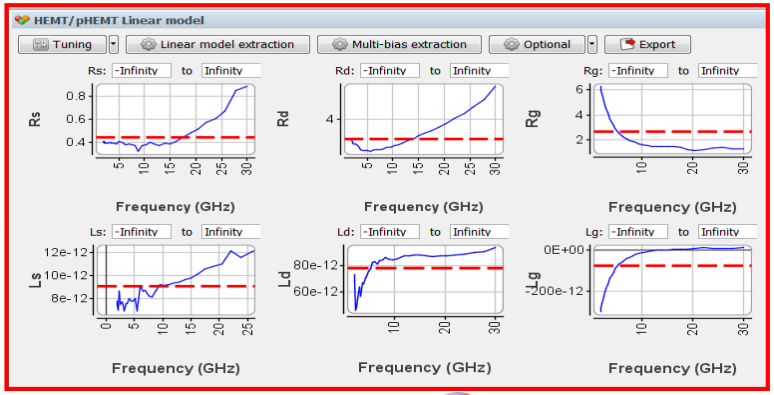
Channel open $V_{gs} >> V_p$

=> **Direct calculus of extrinsic parameters without optimization**

Rs = real(Z21)-Rc/2
Rd = real (Z22)-real(Z21)-Rc/2
Rg ≈ real(Z11)-real(Z21)+Rc/6

Ls = Im(Z21)/W
Ld = (Im(Z22)-Im(Z21))/W
Lg = (Im(Z11)-Im(Z21))/W





AMCAD Engineering
Advanced Modeling for Computer-Aided Design

Small Signal FET modeling

- **Step 2 (optional) :** Extrinsic parameters initialization with cold FET measurements

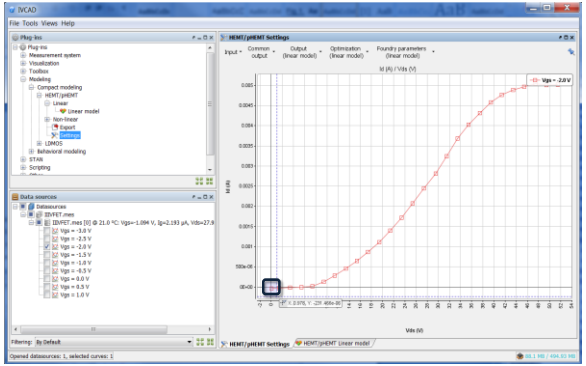
$$\mathrm{Im}(Y_{11}) = j\omega.(Cpg+2Cb)$$

$$\mathrm{Im}(Y_{21}) = \mathrm{Im}(Y_{12}) = -j.\omega.Cb$$

$$\mathrm{Im}(Y_{22}) = j.\omega.(Cb+Cpd)$$

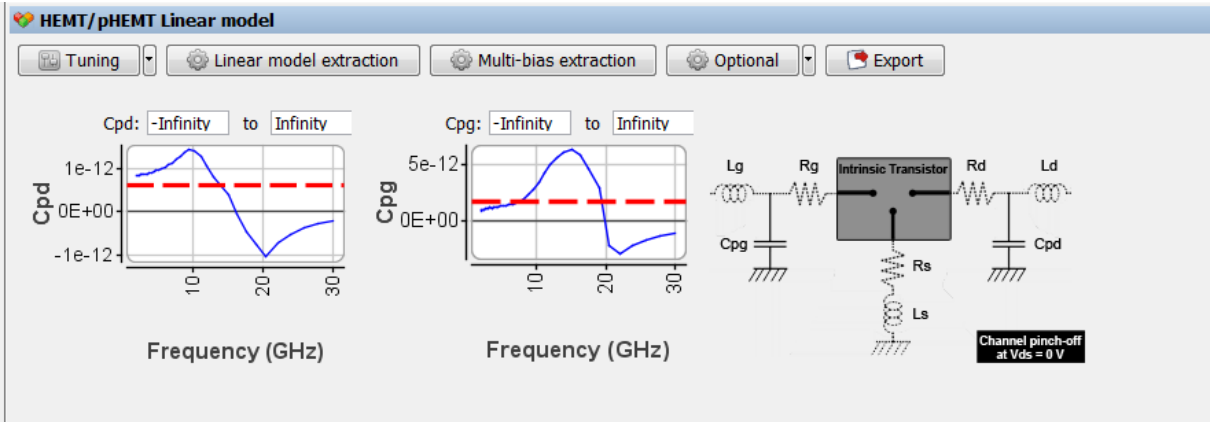
V_{ds} = 0 V

Channel pinch-off $V_{gs} < V_p$



=> Direct calculus of extrinsic parameters without optimization

```
Cpd = (Im(Y22)+Im(Y21))/W
Cpg = ((Im(Y11)+2*Im(Y21))/W
```

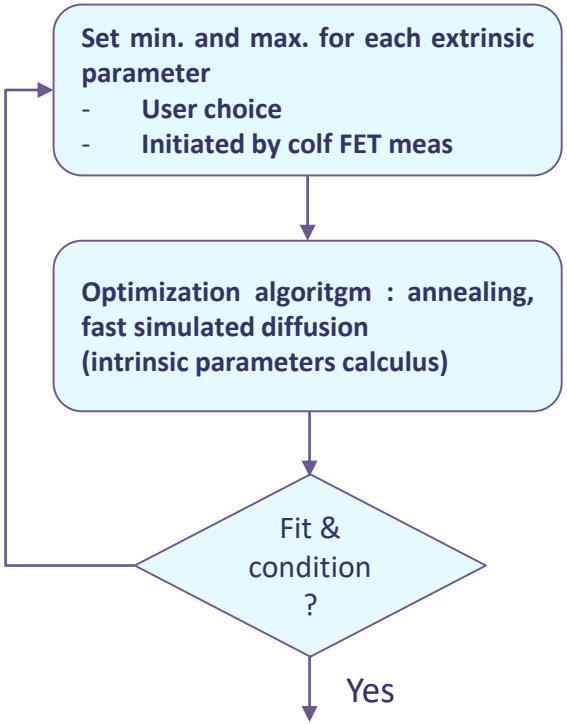


Small Signal FET modeling

- **Extraction of extrinsic and intrinsic parameters:**

For a given set of extrinsic parameters, intrinsic admittance matrix of the device is extracted from measured [S] parameters

Condition : There is only one set of extrinsic parameters for which intrinsic parameters are frequency independent.

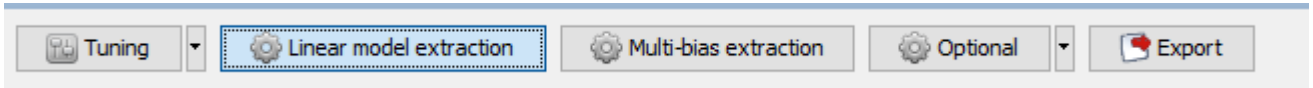


Multi-biasing extraction of linear model

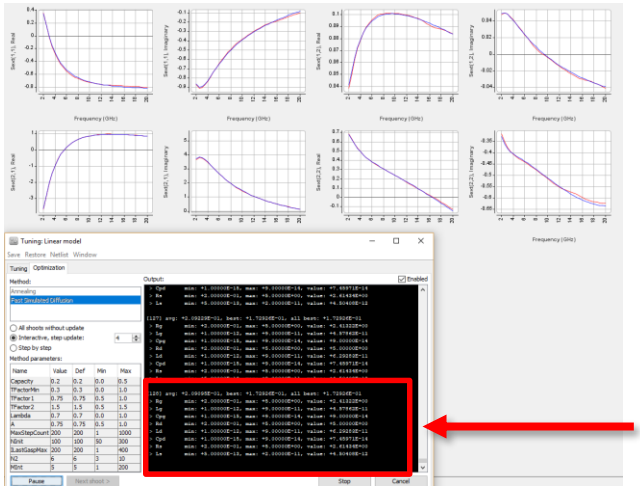
Small Signal FET modeling

- **Step 3** : Linear model optimization

Comparison and optimization between calculus and measurement can be done for [S], [Y] or [Z] parameters.



After selecting Linear Model, tuning and optimization are accessible.



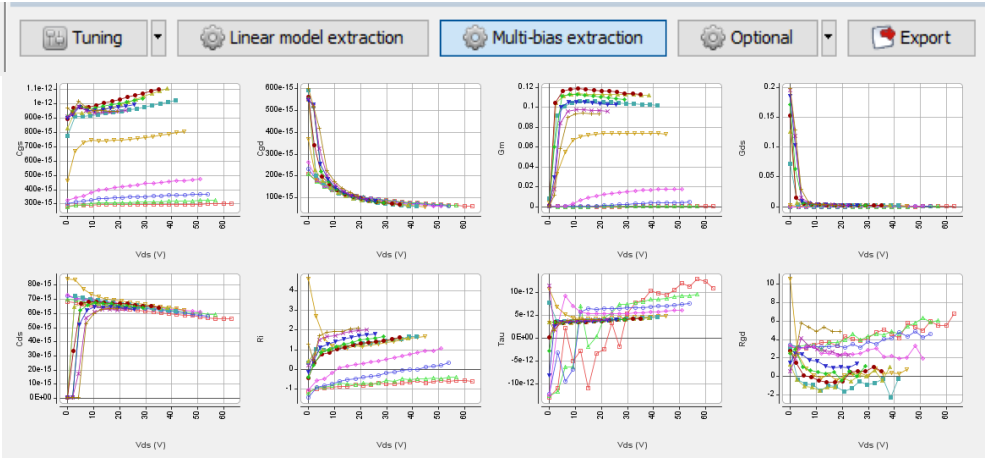
The final and optimized set of parameters.
During the optimization, the updated data are displayed in real time.

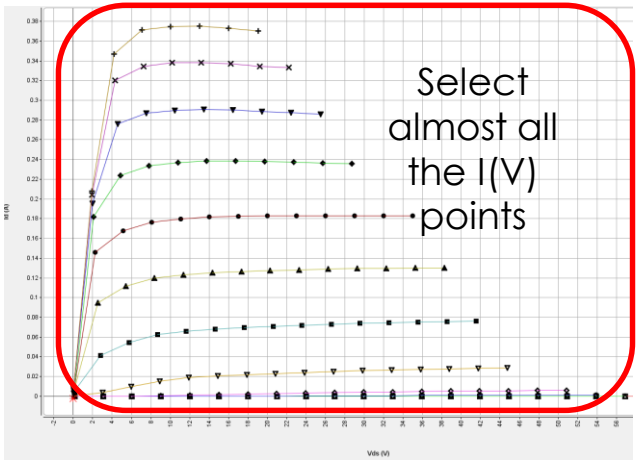
AMCAD Engineering
Advanced Modeling for Computer-Aided Design

Small Signal FET modeling

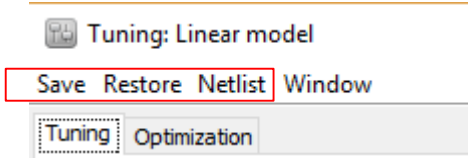
- Step 4 : Multi-bias extraction

To check the good behavior of the linear model with the optimized set of parameters, visualize the intrinsic parameters in multi-bias conditions.





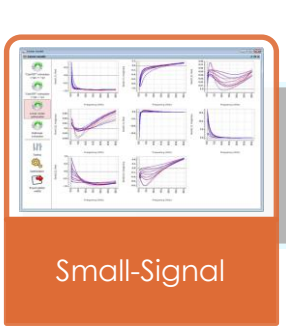
If the intrinsic curves have a good trend, all these parameters can be stored into a buffer or in Netlist file .

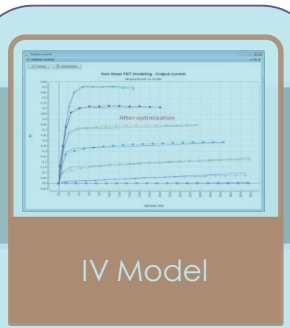


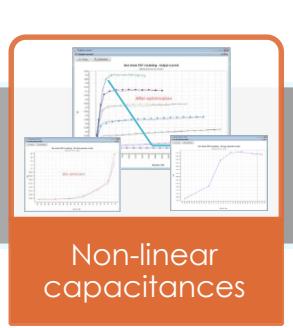
Settings : model output, intrinsic parameters;
-> linear model extraction

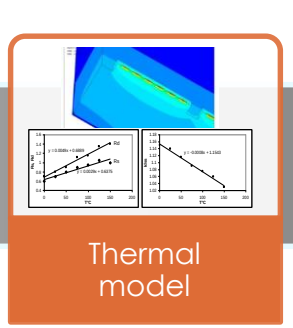
AMCAD Engineering
Advanced Modeling for Computer-Aided Design

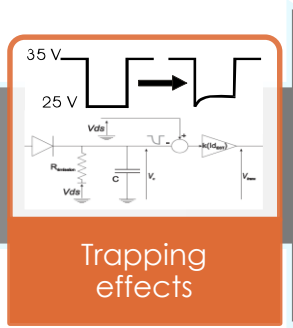
Model Extraction flow











R_i
C_{ds}
τ
G_m
G_d
C_{gs}
C_{gd}
C_{ds}
R_{gd}

$I_{gs}=f(V_{gs},V_{ds})$

$I_{ds}=f(V_{gs},V_{ds})$

R_g
L_g
C_{pg}
L_s
C_{pd}
L_d
R_s
R_d

$C_{gs}=f(V_{gs})$
$C_{gd}=f(V_{gd})$
$C_{ds}=f(V_{ds})$

$I_g=f(V_{gs},T)$
$I_{ds}=f(V_{gs},V_{ds},T)$

Opt1:
$C_{gs}=f(V_{gs})$
$C_{gd}=f(V_{gd})$
$C_{ds}= f(V_{ds})$

Opt2:
$I_{ds}=f(V_{gs\_trap},V_{ds\_trap},T)$

$R_s=f(T)$
$R_d=f(T)$

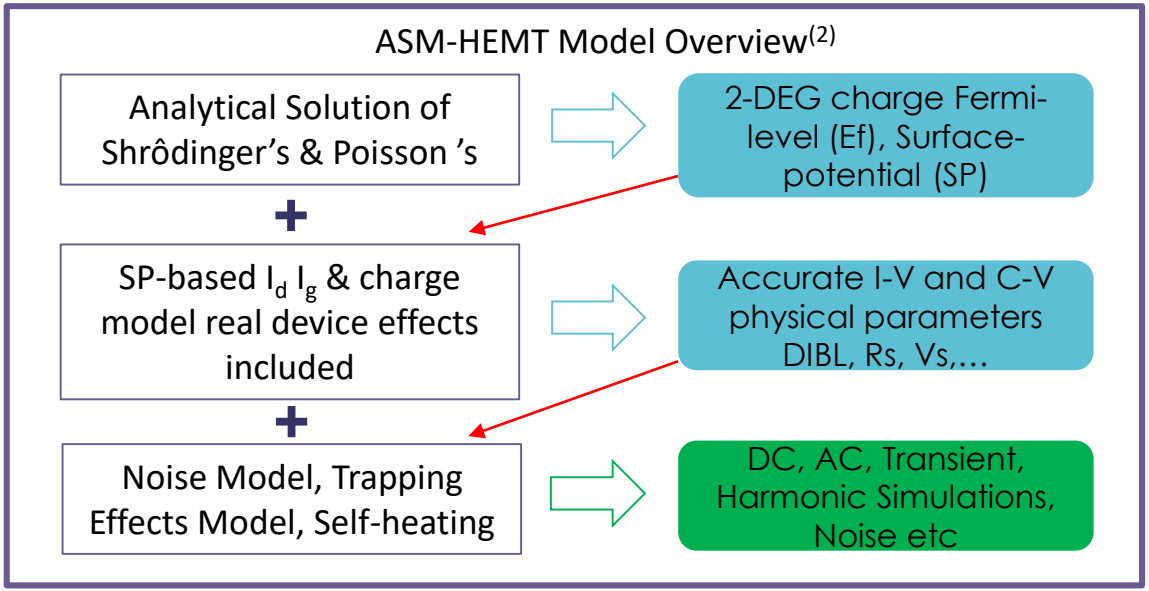
AMCAD Engineering
Advanced Modeling for Computer-Aided Design

GaN HEMT modeling

ASM linear model is based on extrinsic parameter AMCAD extraction flow in IVCAD

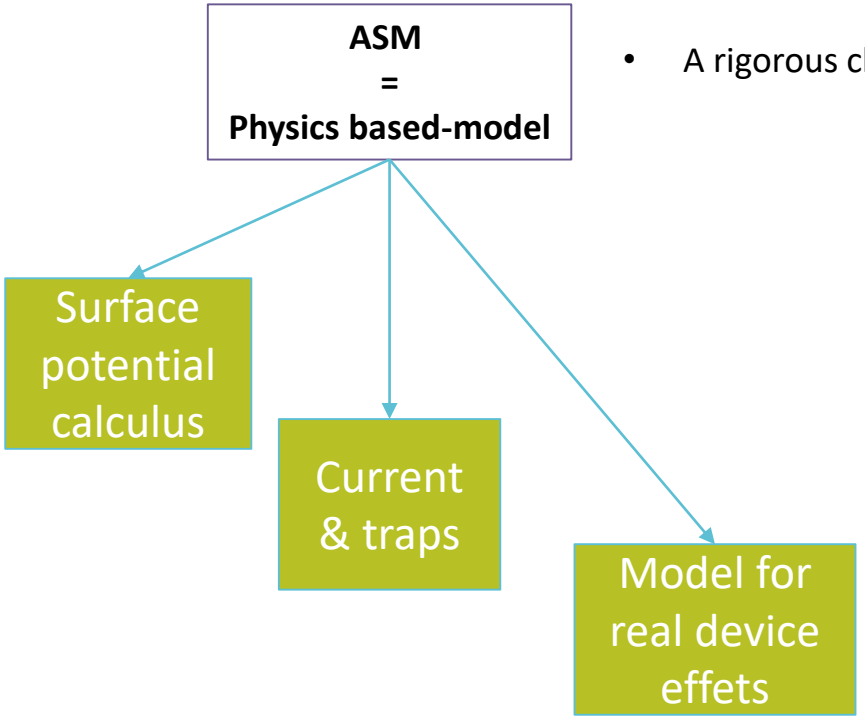
Advanced Spice Model [1] is a CMC candidate models for industry standardization in 2018

ASM is one of the 2 candidates for the **C**ompact **M**odel **C**oalition with MIT model (MVSG)



(1) http://iitk.ac.in/asm/
(2) Industry Standard GaN HEMT compact model for power electronics and RF applications, Dr Yogesh S. Chauhan

ASM GaN industry standard



- The variation of E_f (Fermi-level) is divided in function of the gate voltage
- A rigorous charge model for all the terminal charge in the device is present

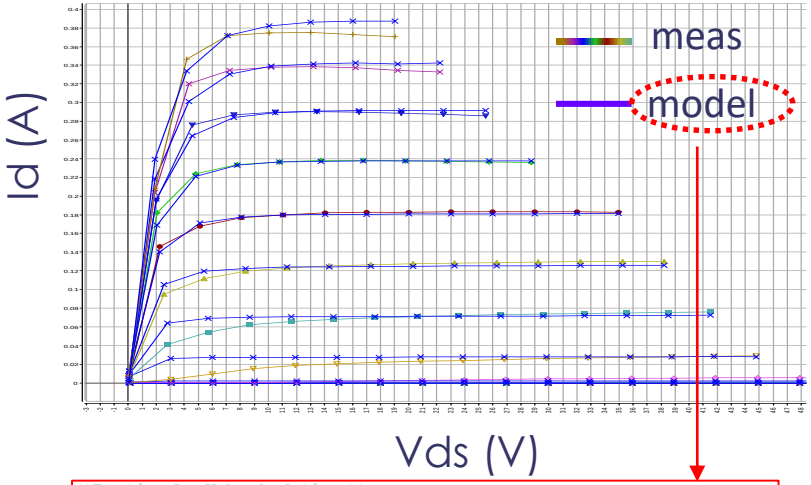
Real Device Effects Incorporated into the model :

- velocity saturation effect
- mobility field dependance
- subthreshold-slope degradation
- NL series résistances
- flicker noise
- channel lentgh modulation
- drain-induced barrier lowering
- self-heating effect
- temperature dependance …

(1) http://iitk.ac.in/asm/
(2) Industry Standard GaN HEMT compact model for power electronics and RF applications, Dr Yogesh S. Chauhan

Output current source : NEW OPTION ➔ ASM

- In addition to the existing AMCAD current source model, the ASM (3) model has just been added in IVCAD.



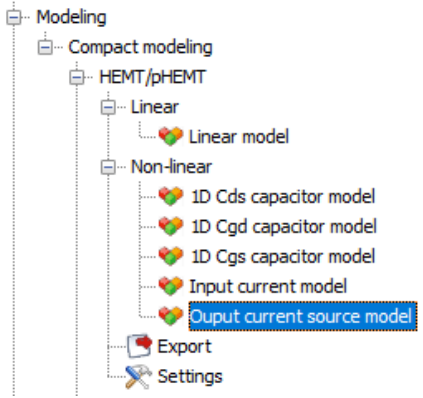

```
/*Function for Vg0 calculation */
Vdsx =sqrt(Vdsi.*Vdsi.+0.01).-0.1;
Voff_dibl=voff-(eta0).*(Vdsx.*vdscale)./sqrt(Vdsx.*Vdsx.+vdscale.*vdscale);
Voff_dibl_temp = Voff_dibl-(Tdev/Tnom-1)*kt1;
cdsc =1.0.+nfactor.+(cdscd).*Vdsx;
Vtv=KboQ.*Tdev.*cdsc;
t0=1./(2.0.*w.*P_Q.*DOS.*Vtv.*Vtv);
vgmin=Voff_dibl_temp.+Vtv.*log(t0.*imin);
vggmin=0.5.*((Vgsi.-vgmin).+sqrt((Vgsi.-vgmin).*(Vgsi.-vgmin).+1.0e-4)).+vgmin;
Vg0= vggmin.-Voff_dibl_temp;

/*Function for PSIS Calculation*/
vgop=0.5.*Vg0 .+ 0.5.*sqrt(Vg0.*Vg0 .+ 4.0.*ep_psi.*ep_psi);
beta=Cg./(P_Q.*DOS.*Vtv);
ALPHAN =exp(1)./beta;
ALPHAD = 1.0./beta;
vgon = vgop.*ALPHAN./(sqrt(vgop.*vgop .+ ALPHAN.*ALPHAN));
vgod = vgop.*ALPHAD./(sqrt(vgop.*vgop + ALPHAD.*ALPHAD));
Hx =(vgop .+ Vtv.*(1.0-log(beta.*vgon)).-(GAMMA0Ival./3.0).*((Cch.*vgop)**(2/3)))
```

Name	Definition	Units	Default
NOF	Number of fingers	none	3.00
Gate_width	Gate width	m	2.00E-4
Gate_length	Gate length	m	2.50E-7
tbar	Barrier layer thickness	m	2.72E-8
vsat	Saturation velocity	m/s	4,20E6
at	Temperature dependence coefficient for saturation velocity	none	0.0
u0val	Low field mobility	m2/(V*s)	0.18
ua	Mobility degradation coefficient first order	V-1	4.40E-9
ub	Mobility degradation coefficient second order	V-2	1.00E-16
ute	Temperature dependence coefficient of mobility	none	1.00
imin	Minimum drain current	A	1.00E-15
voff	Pinch off voltage	V	-2.608
lambda	Channel length modulation coefficient	V-1	-3.5E-3
delta	Exponent for Vdeff coefficient	none	0.67
thesat	Velocity saturation parameter	V-2	1.37
nfactor	Sub-voff slope parameters	none	4.64
cdscd	Sub-voff slope change due to drain voltage	None	0.19
epsilon	Dielectric Permittivity of AlGaN layer	F/m	10.66E-11
eta0	DIBL Parameter	none	1E-9
vdscale	DIBL Scaling VDS	V	5
gdsmin	Convergence parameter	S	1.0E-12

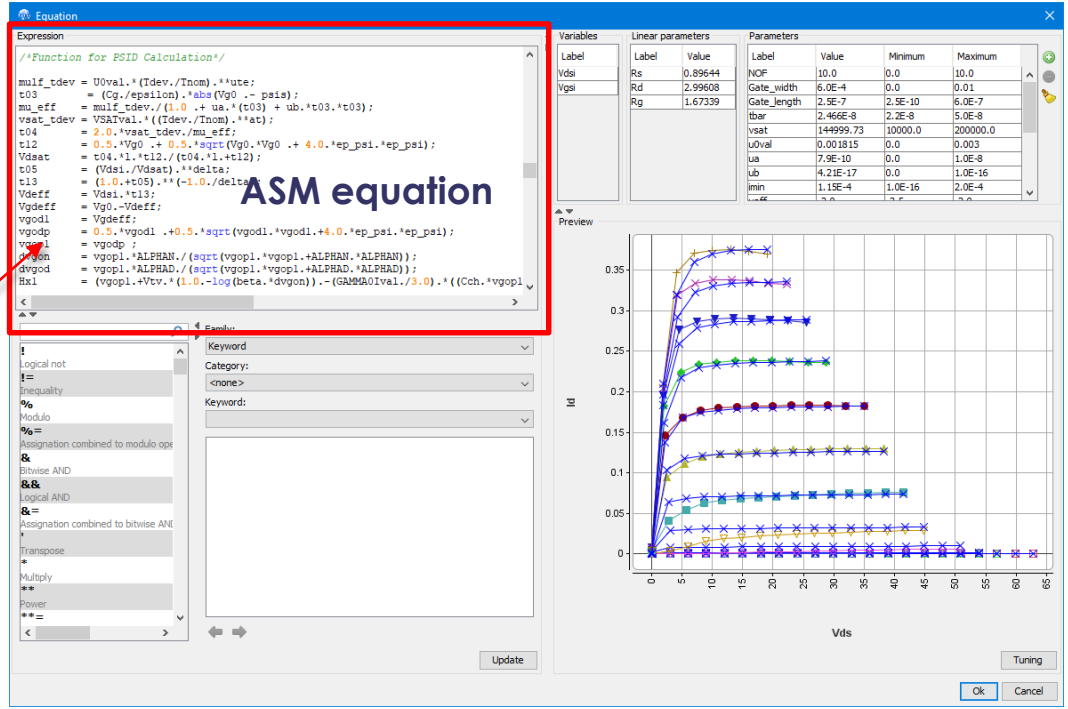
(3) *Sourabh Khandelwal, Sudip Ghosh, Sheikh Aamir Ahsan, Avirup Dasgupta, and Yogesh Singh Chauhan, « ASM-HEMT 101.0.0 Advanced SPICE Model for HEMTs - Technical Manual », March 16, 2018.*

Output Current Source

The extrinsic parameters values are common to the linear and non-linear model.



For the nonlinear part it is possible to use the AMCAD model or a custom model.

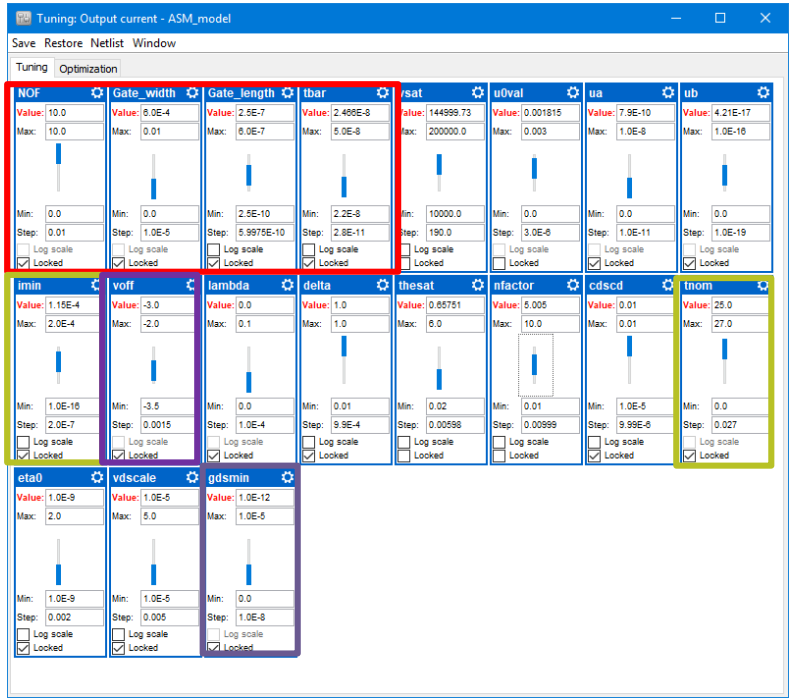


Equation editor is implemented to allow the customer to build his custom model.

AMCAD Engineering
Advanced Modeling for Computer-Aided Design

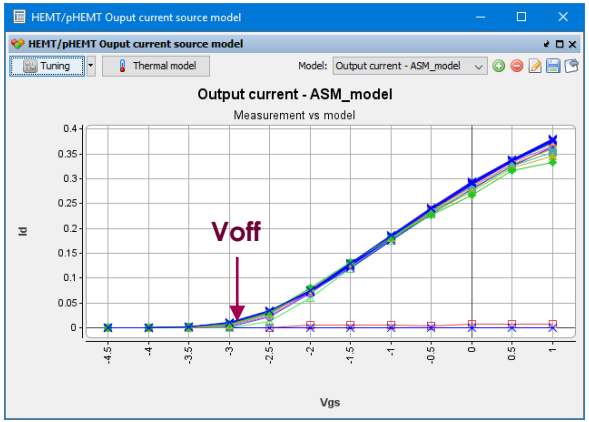
Output Current Source

Model optimization methodology



Locked Parameters

- Physical parameters
- Nominal T° measurements
- Convergence parameters
- Imin : Pinch off Current
- Voff : Pinch off Voltage
- …



AMCAD Engineering
Advanced Modeling for Computer-Aided Design

Diodes : NEW OPTION → ASM

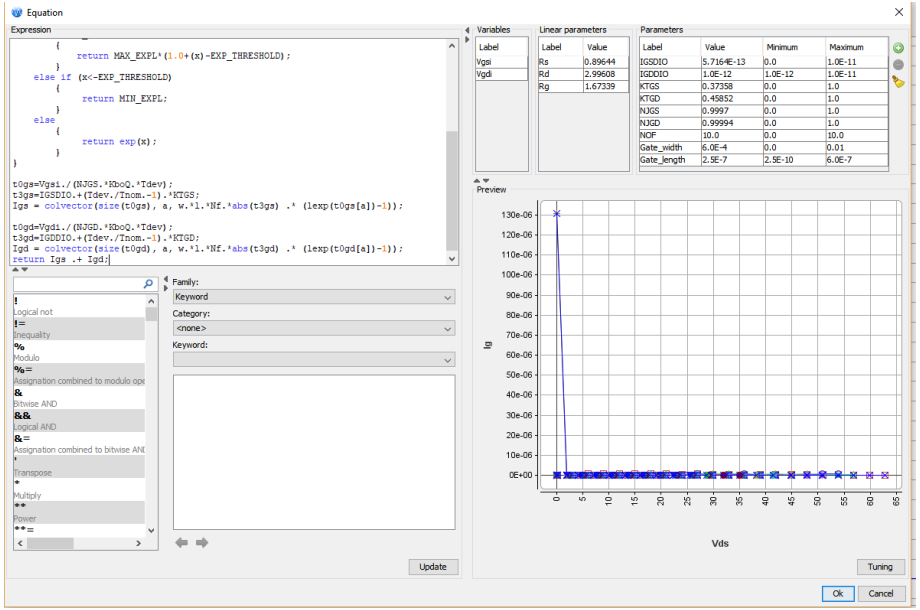
- Gate-drain and gate-source diode equations :

$$I_{gs} = w * l * nf * |t_3| * (exp^{t_0} - 1)$$

- $t_0 = \frac{V_{gsi}}{njgs * KboQ * T_{dev}}$
- $t_3 = igsdio + \left(\frac{T_{dev}}{T_{nom}} - 1\right) * ktgs$

$$I_{gd} = w * l * nf * |t_3| * (exp^{t_0} - 1)$$

- $t_0 = \frac{V_{gsi}}{njgd * KboQ * T_{dev}}$
- $t_3 = igddio + \left(\frac{T_{dev}}{T_{nom}} - 1\right) * ktgd$

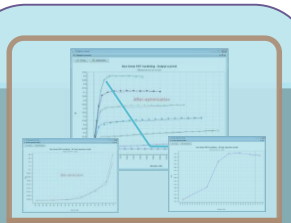


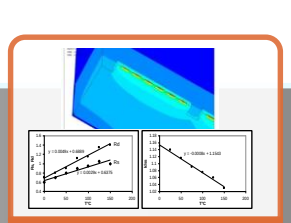
Name	Definition	Units	Default
igsdio	Gate-source junction diode saturation current	A/m^2	1
njgs	Gate-source junction diode current ideality factor	None	2.5
igddio	Gate-drain junction diode saturation current	A/m^2	1
njgd	Gate-drain junction diode current ideality factor	None	2.5
ktgs	Temperature co-efficient of gate-source junction diode current	None	0
ktgd	Temperature coefficient of gate-drain junction diode current	None	0

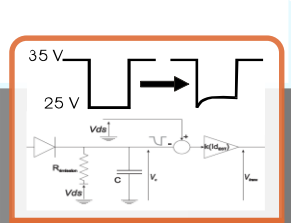
Model Extraction Flow


Small-Signal


IV Model


Non-linear capacitances


Thermal model



Trapping effects

R_i
C_{ds}
τ
G_m
G_d
C_{gs}
C_{gd}
C_{ds}
R_{gd}

$I_{gs}=f(V_{gs},V_{ds})$

$I_{ds}=f(V_{gs},V_{ds})$

R_g
L_g
C_{pg}
L_s
C_{pd}
L_d
R_s
R_d

$C_{gs}=f(V_{gs})$
$C_{gd}=f(V_{gd})$
$C_{ds}=f(V_{ds})$

$I_g=f(V_{gs},T)$
$I_{ds}=f(V_{gs},V_{ds},T)$

Opt1:
$C_{gs}=f(V_{gs})$
$C_{gd}=f(V_{gd})$
$C_{ds}= f(V_{ds})$

Opt2:
$I_{ds}=f(V_{gs\_trap},V_{ds\_trap},T)$

$R_s=f(T)$
$R_d=f(T)$

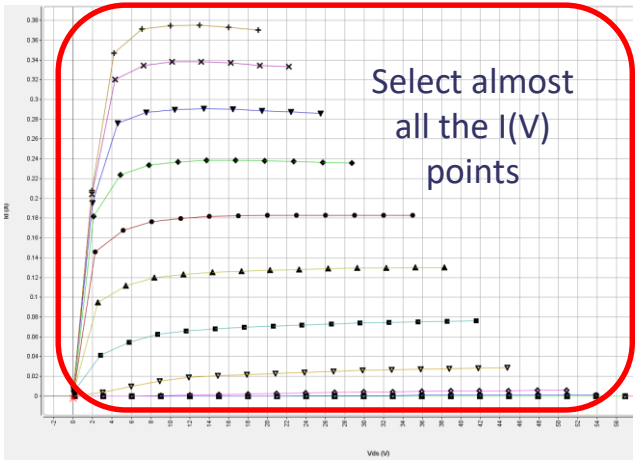
AMCAD Engineering
Advanced Modeling for Computer-Aided Design

Non-linear capacitances : NEW OPTION ➔ ASM

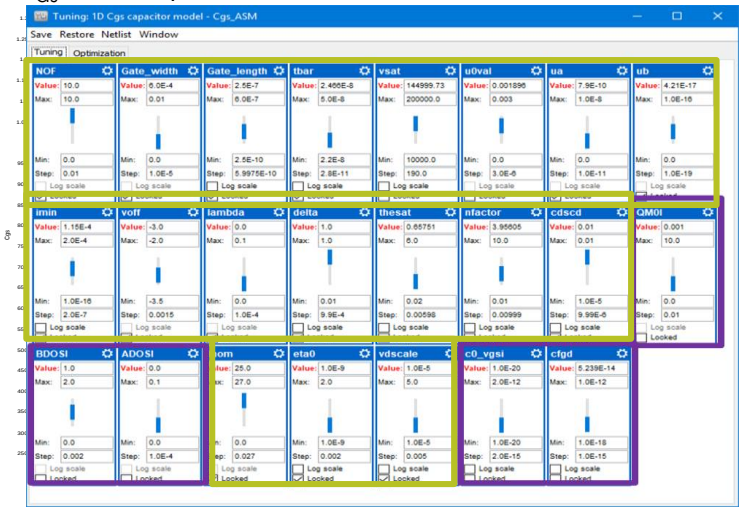
C_{gs}

- Input capacitance C_{gs} is strongly influenced by V_{gs} and weakly influenced by V_{ds}.

In ASM model the C_{gs} capacitance depends on both V_{gs} & V_{ds}, 2D capacitance.



Reuse of the current source parameters




```
/*QGI_gate_charge_calculation*/

t1g = psid .- psis;
t2g = Vg0 .+ Vtv .- psim;
t3g = (Cg.*w.*Nf.*l).*(Vg0.-psim.+0.5.*t1g.*t1g./(6.0.*t2g));
T0g = 1e+26.*(t3g./QM0I);
T1g = 1.0 .+ (T0g.**BDOSI);
XDCinv = ADOSI./T1g;
Cg_qme = epsilon./(tbar .+ XDCinv);
qgint = (Cg_qme.*w.*Nf.*l).*(Vg0.-psim.+0.5.*t1g.*t1g./(6.0.*t2g)).+c0_vgsi.*Vgsi.+cfgd.*Vgsi;
```

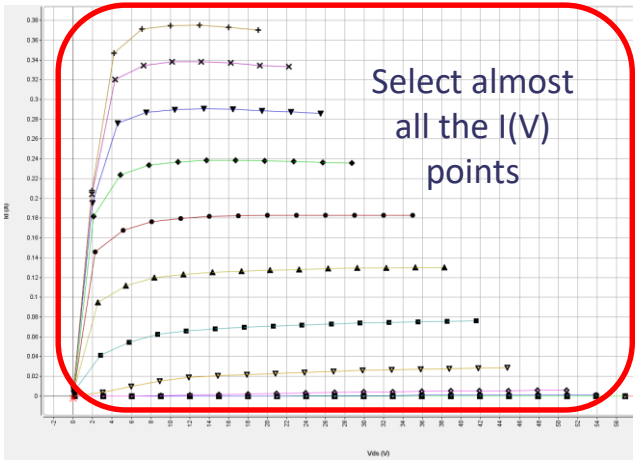
Name	Definition	Units	Default
QM0I	Charge centroid parameter - starting point for QME in inversion	none	1E-3
BDOSI	Charge centroid parameter - slope of CV curve under QME in inversion	none	1
ADOSI	Quantum mechanical effect pre-factor cum switch in inversion	none	0
cgso	Gate-source overlap capacitance	F	0.0E-18
cfgd	Fringing capacitance parameter	F	1E-13

Non-linear capacitances : NEW OPTION ➔ ASM

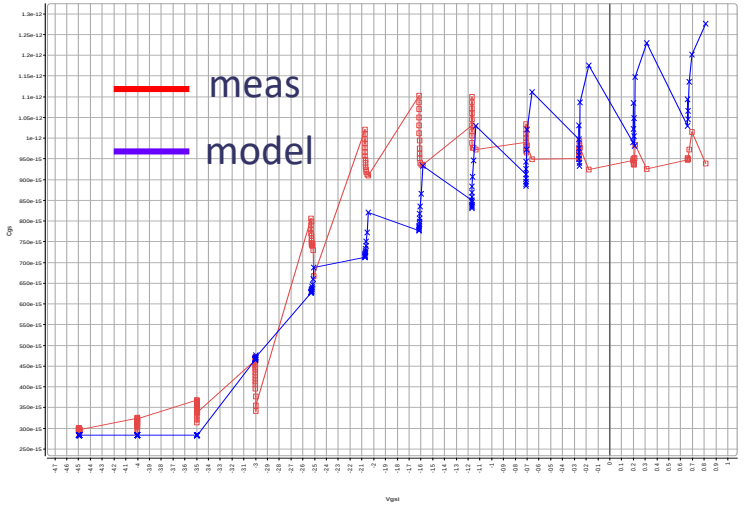
C_{gs}

- Input capacitance C_{gs} is strongly influenced by V_{gs} and weakly influenced by V_{ds}.

In ASM model the C_{gs} capacitance depends on both V_{gs} & V_{ds}, 2D capacitance.



C_{gs} capacitance extracted on the entire I(V) network




```
/*QGI_gate_charge_calculation*/

t1g = psid .- psis;
t2g = Vg0 .+ Vtv .- psim;
t3g = (Cg.*w.*Nf.*l).*(Vg0.-psim.+0.5.*t1g.*t1g./(6.0.*t2g));
T0g = 1e+26.*(t3g./QM0I);
T1g = 1.0 .+ (T0g.**BDOSI);
XDCinv = ADOSI./T1g;
Cg_qme = epsilon./(tbar .+ XDCinv);
qgint = (Cg_qme.*w.*Nf.*l).*(Vg0.-psim.+0.5.*t1g.*t1g./(6.0.*t2g)).+c0_vgsi.*Vgsi.+cfgd.*Vgsi;
```

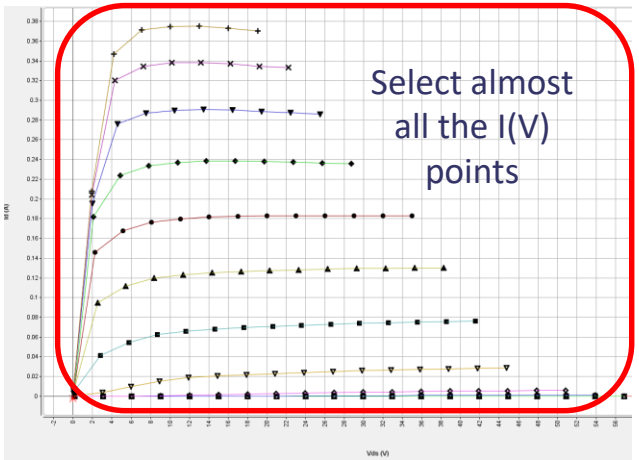
Name	Definition	Units	Default
QM0I	Charge centroid parameter - starting point for QME in inversion	none	1E-3
BDOSI	Charge centroid parameter - slope of CV curve under QME in inversion	none	1
ADOSI	Quantum mechanical effect pre-factor cum switch in inversion	none	0
cgso	Gate-source overlap capacitance	F	0.0E-18
cfgd	Fringing capacitance parameter	F	1E-13

Non-linear capacitances : NEW OPTION ➔ ASM

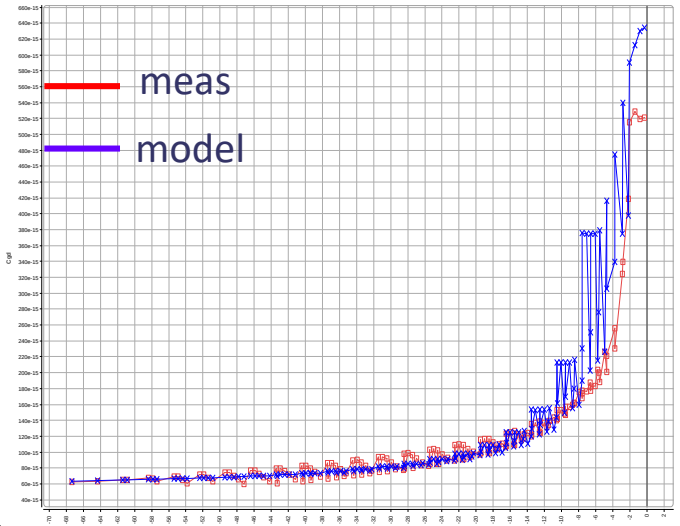
C_{gd}

- Feedback capacitance C_{gd} is a strong function of drain voltage.

Inclusion of this effect is necessary to fit large-signal data.



C_{gd} capacitance extracted on the entire I(V) network



Name	Definition	Units	Default
vdsatcv	Saturation voltage on drain side in CV Model	V	100
cgdo	Gate-drain overlap capacitance	F	0.0E-18
cgdl	Vds bias dependence of parasitic gate drain overlap capacitance	F	0.0E-15
cfgd	Fringing capacitance parameter	F	1E-12
ktcfgd	Temperature dependence of Fringing capacitance	F	0
cfgdsm	Capacitance smoothing parameter	F	1E-24

```
VdeffCV     = (Vdsi.*vdsatcv)./sqrt(Vdsi.*Vdsi.+vdsatcv.*vdsatcv);
cgdvar      = cgdo.-cgdl.*VdeffCV;
qfrl        = cfgd0.-(cfgd.+(Tdev./Tnom.-1).*ktcfgd).*Vdsi;
qfr         = 1e-25.+qfrl.-0.5.*(1e-25.+qfrl.-sqrt((qfrl.-1e-25).*(qfrl.-1e-25).+cfgdsm));
qdov        = cgdvar.*Vgdi;
```

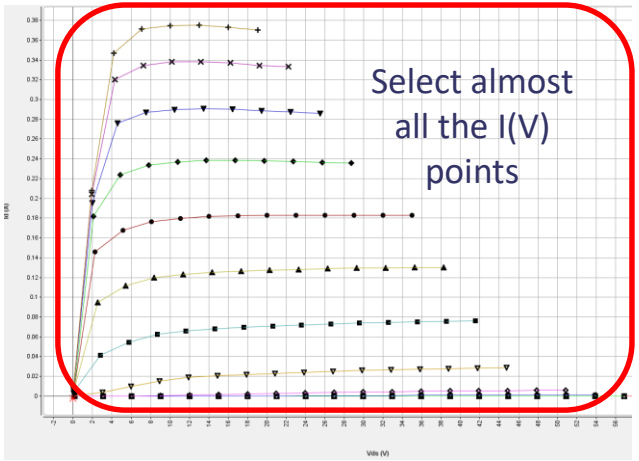
Reuse of C_{gs} capacitance parameter

AMCAD Engineering
Advanced Modeling for Computer-Aided Design

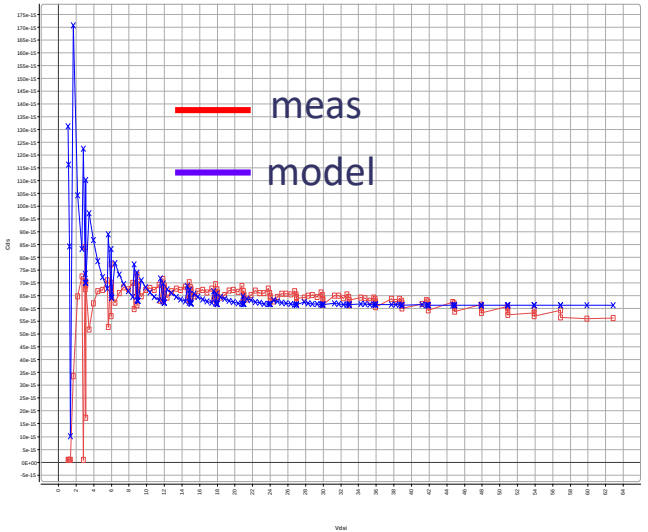
Non-linear capacitances : NEW OPTION ➔ ASM

C_{ds}

- It is possible to have a C_{ds} capacitance function of the V_{ds} voltage.



C_{ds} capacitance extracted on the entire I(V) network

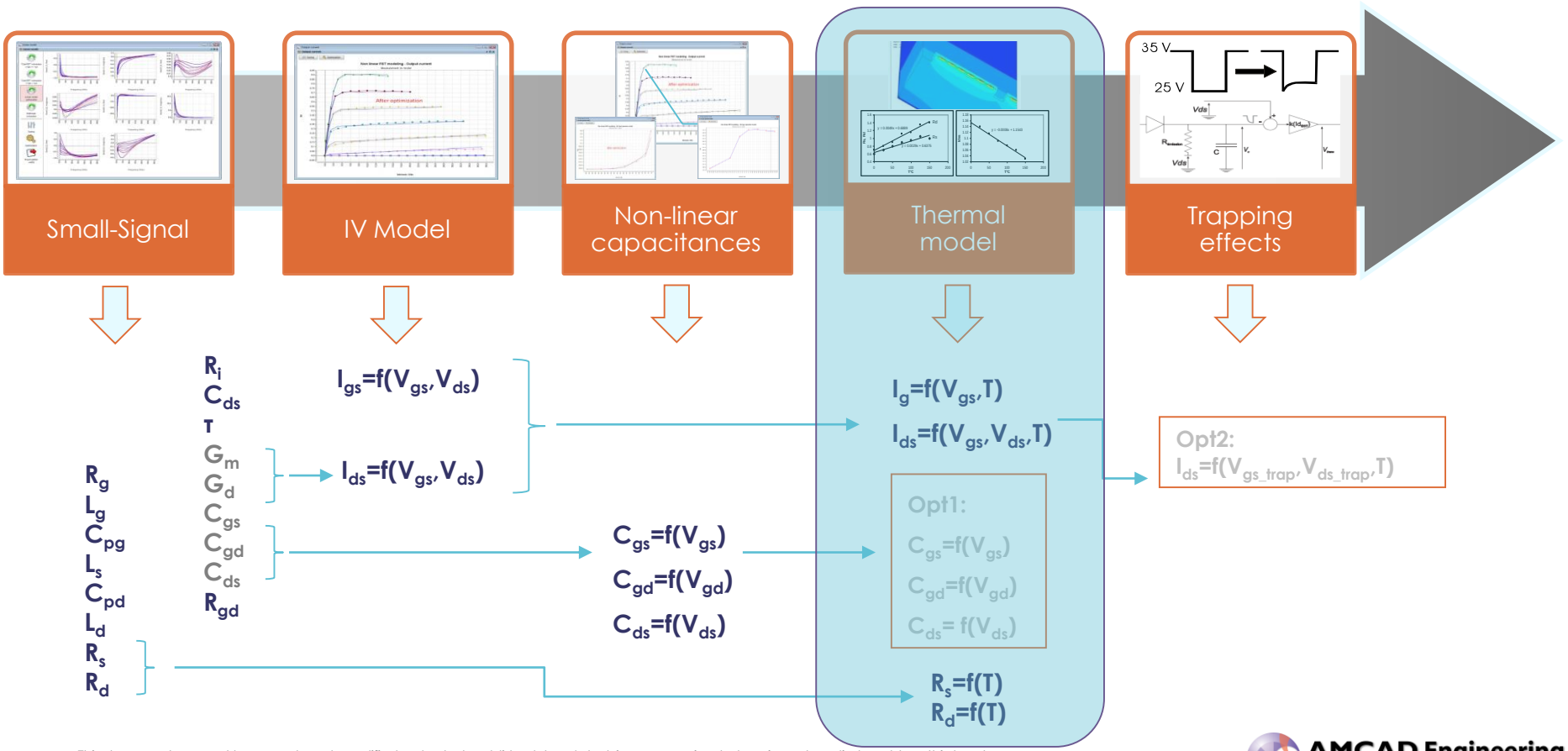


Name	Definition	Units	Default
cdso	Cds capacitance parameter	F	0E-18
vbi	Built in potential	V	0.9
cj0	Zero bias depletion capacitance	F	0E-15
mz	Grading factor of depletion capacitance	None	0.5
aj	Limiting factor of depletion capacitance in forward bias region	None	100E-3
dj	Fitting parameter	None	1

```
/*QDI_drain_charge_Calculation*/

t0d = Vg0 .+ Vtv .- psim;
t1d = (psis .+ 2.0.*psid)./3.0;
t2d = (1/12).*(psisd.*psisd)./t0d;
t3d = (1/120).*(psisd.*psisd.*psisd)./(t0d.*t0d);
t0qdep=(vbi .- (Tdev./Tnom .- 1.0).*ktvbi).*(1.0.-exp(-log(aj)./mz));
Vth= KboQ.*Tdev;
t1qdep=(t0qdep.+Vdsi)./Vth;
t2qdep=sqrt(dj.*t1qdep.*t1qdep.+ 1.92);
t3qdep=(t1qdep.+t2qdep)*0.5;
t4qdep=t0qdep.-Vth.*t3qdep;
t6qdep=log(1.0.-t4qdep./vbi);
t8qdep=cj0.*(vbi .- (Tdev./Tnom .- 1.0).*ktvbi).*(1.0.-exp(t6qdep.*(1.0.-mz))./(1.0.-mz);
Qdep=t8qdep+aj*cj0*(-Vdsi-t4qdep);
gdint = -(Cg_qme.*w.*l.*Nf.*0.5).*(Vg0 .- t1d .+ t2d .+ t3d);
```

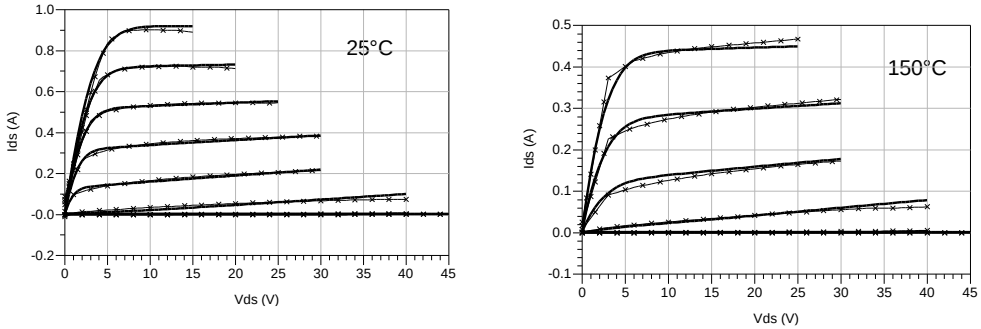

AMCAD Engineering
Advanced Modeling for Computer-Aided Design

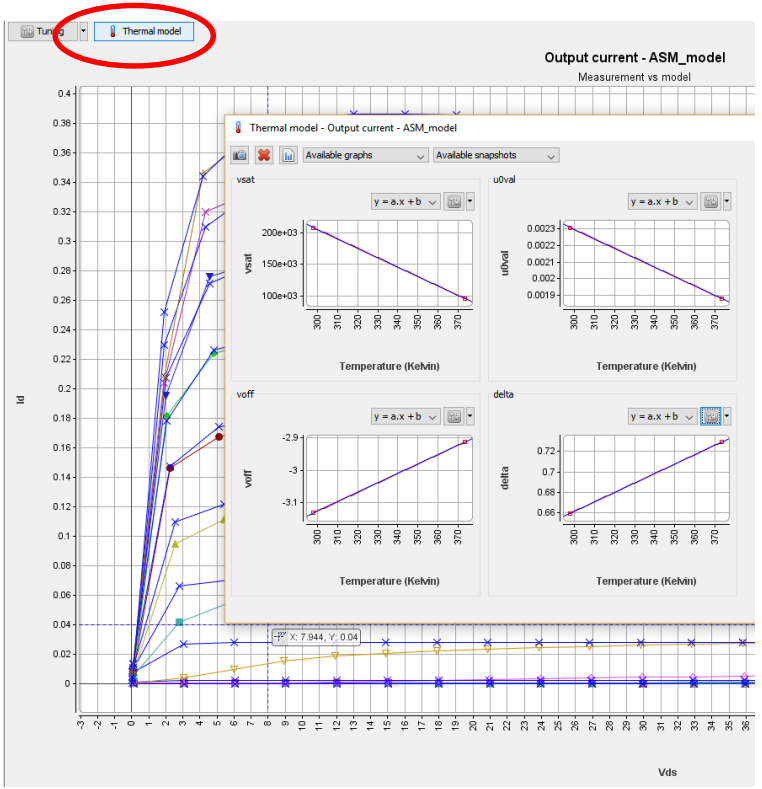
Model Extraction Flow



Thermal effects with IVCAD

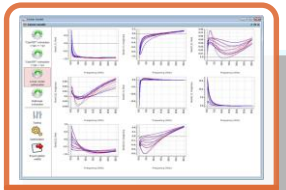
- Temperature dependence with ambient or chuck temperature



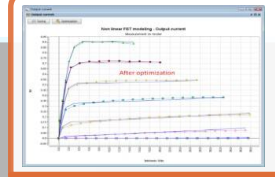


IVCAD can be use to model thermal effects on different parameters of current source and capacitances.

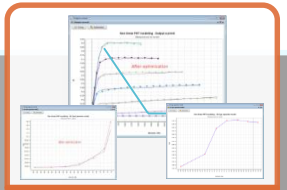
Model Extraction Flow



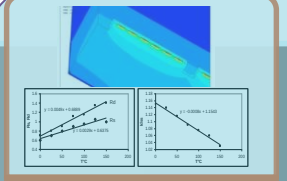
Small-Signal



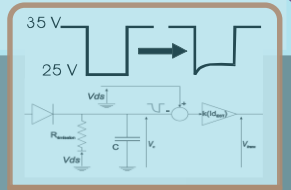
IV Model



Non-linear capacitances



Thermal model



Trapping effects

R_i
C_{ds}
τ
G_m
G_d
C_{gs}
C_{gd}
C_{ds}
R_{gd}

$I_{gs}=f(V_{gs},V_{ds})$

$I_{ds}=f(V_{gs},V_{ds})$

R_g
L_g
C_{pg}
L_s
C_{pd}
L_d
R_s
R_d

$C_{gs}=f(V_{gs})$
$C_{gd}=f(V_{gd})$
$C_{ds}=f(V_{ds})$

$I_g=f(V_{gs},T)$
$I_{ds}=f(V_{gs},V_{ds},T)$

Opt1:
$C_{gs}=f(V_{gs})$
$C_{gd}=f(V_{gd})$
$C_{ds}=f(V_{ds})$

Opt2:
$I_{ds}=f(V_{gs\_trap},V_{ds\_trap},T)$

$R_s=f(T)$
$R_d=f(T)$

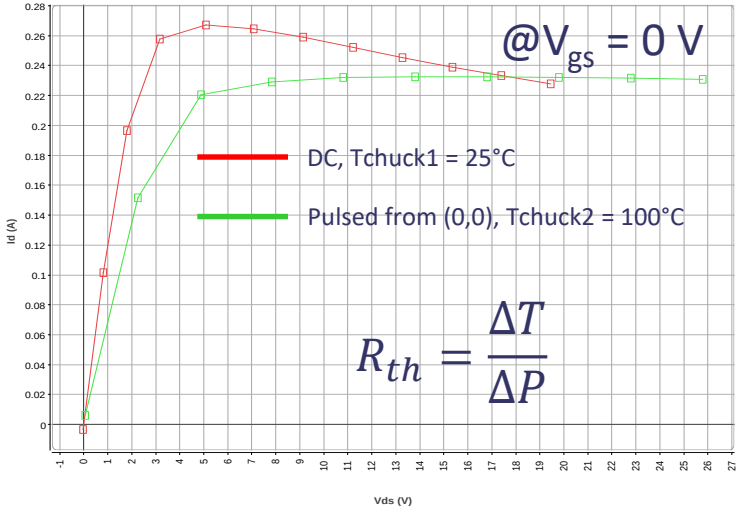
Thermal and Trapping effects

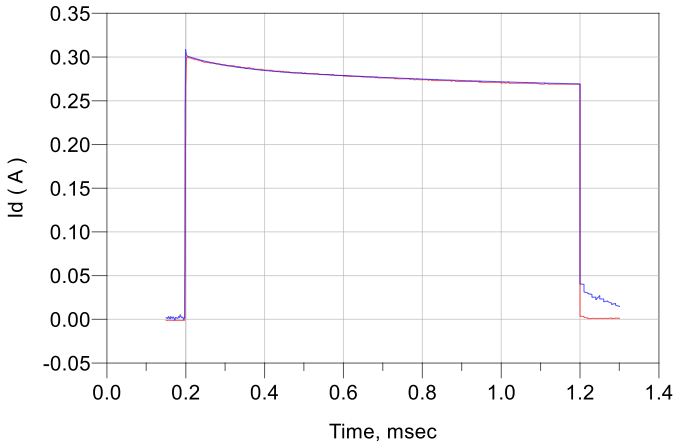
- Thermal and Trapping effects require a time-based simulator. IVCAD software does not have an on-board simulator. That's why, the thermal and trapping effect included in AMCAD models are implemented using commercial software like Advanced Design System.

Trapping Effects :

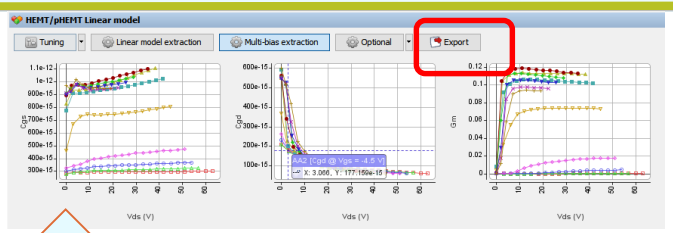
➔ Gate-lag & Drain-Lag measurements.

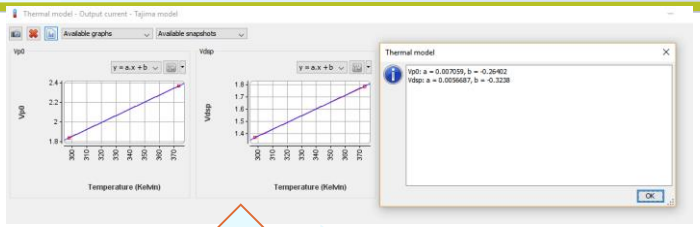
Thermal resistance extraction ➔ Coincidence method / Del Alamo method
Thermal impedance extraction ➔ Drain long pulse characterization





Export





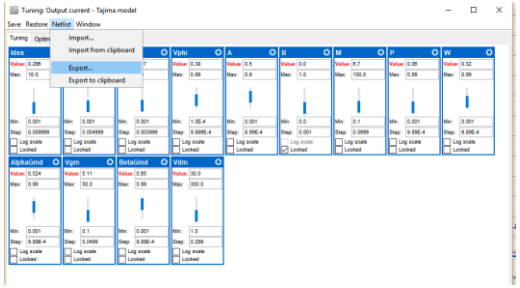
Small-Signal

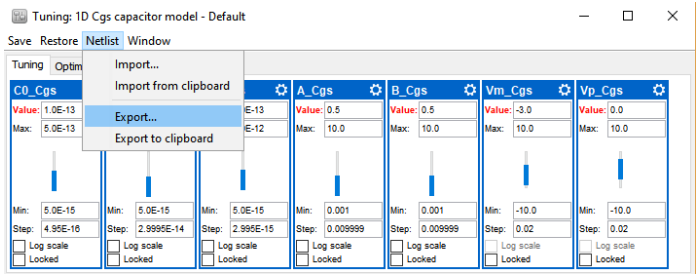
IV Model

Non-linear capacitances

Thermal model

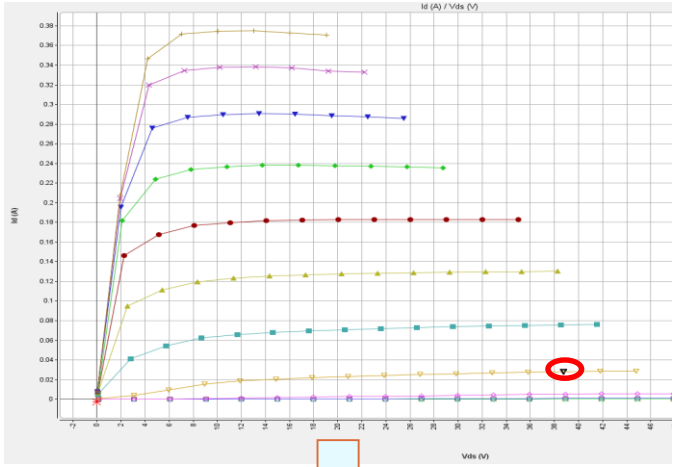
Commercial Simulators

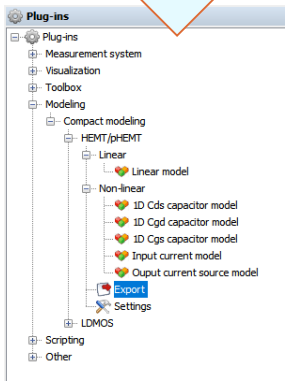




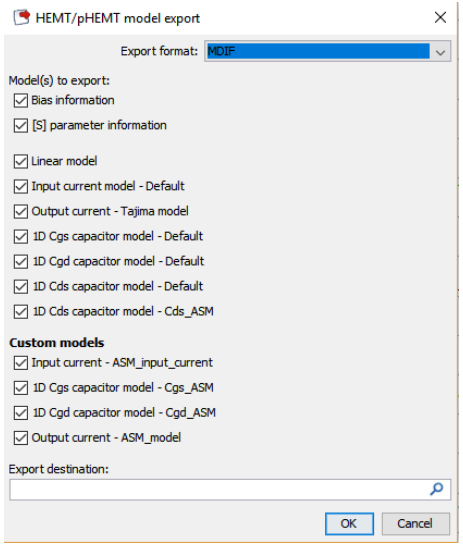
AMCAD Engineering
Advanced Modeling for Computer-Aided Design

Export





- To export the nonlinear model, select only one point of the I(V) network.

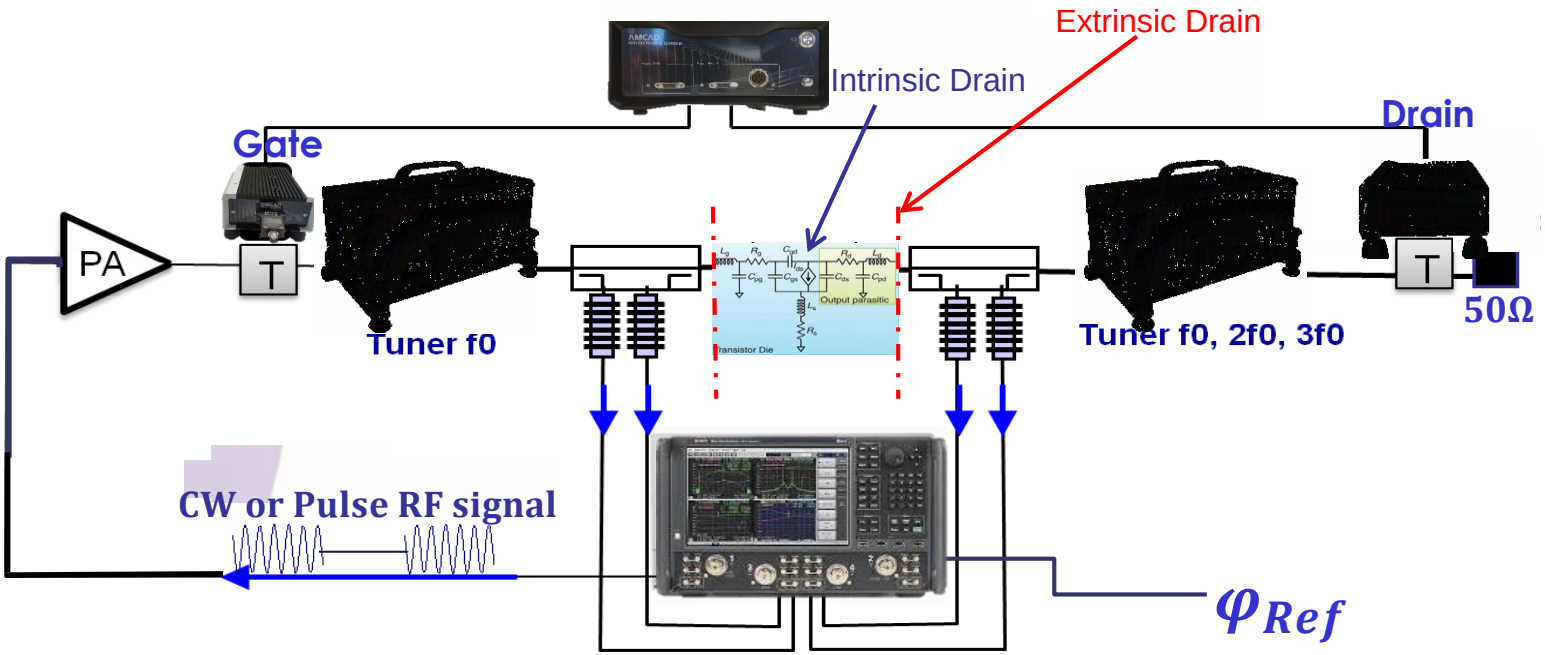


Example netlist file

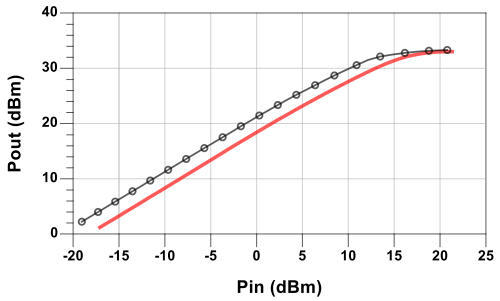
```
*Generated by IVCAD at 2019/01/09 14:56:08

.subckt setofparameters
.param Rg={+1.6733900E+00}
.param Lg={+4.5205000E-11}
.param Cpg={+3.3377000E-14}
.param Rd={+2.9960800E+00}
.param Ld={+8.0146000E-11}
.param Cpd={+5.1630000E-14}
.param Rs={+8.9644000E-01}
.param Ls={+1.0562000E-12}
.param Cgs={+7.8954156E-13}
.param Cgd={+6.5817721E-14}
.param Gm={+7.3612925E-02}
.param Gds={+1.5453619E-03}
.param Cds={+6.3788312E-14}
.param Ri={+1.5815476E+00}
.param Tau={+4.7263491E-12}
.param Rgd={+4.3124969E-01}
.param NOF={+1.0000000E+01}
.param Gate_width={+6.0000000E-04}
.param Gate_length={+2.5000000E-07}
.param tbar={+2.4660000E-08}
.param vsat={+2.9913743E+05}
.param at={-5.6683370E+01}
.param u0val={+9.9113100E+00}
.param ua={+7.0052000E-09}
.param ub={+2.6365000E-17}
.param ute={-6.8681200E+00}
.param imin={+7.1670000E-16}
.param voff={+4.5386000E+00}
.param ktl={-4.1178100E+00}
.param lambda={+7.2807500E+00}
.param delta={+5.3658200E+00}
.param thesat={+4.4347400E+00}
.param nfactor={+9.0676100E+00}
.param cdscd={+3.7488000E-01}
.param QM0I={+4.1304500E+00}
.param BDOSI={+3.0284000E-01}
.param ADOSI={+4.0028000E-03}
.param c0_vdsi={+2.3250000E-13}
.param epsilon={+1.2185000E-10}
.param tnom={+3.7150900E+00}
.param eta0={+1.0000000E-09}
.param vdscale={+5.0000000E+00}
.param c0_vgsi={+3.0649000E-13}
.param vbi={+6.7875200E+00}
.param cj0={+2.9326000E-14}
.param ktvbi={+0.0000000E+00}
.param mz={+6.0603000E-01}
.param aj={+1.7239200E+00}
.param dj={+2.3149000E-01}
.param IGSDIO={+0.0000000E+00}
.param IGDDIO={+1.0000000E-12}
.param KTGS={+5.0000000E-01}
```

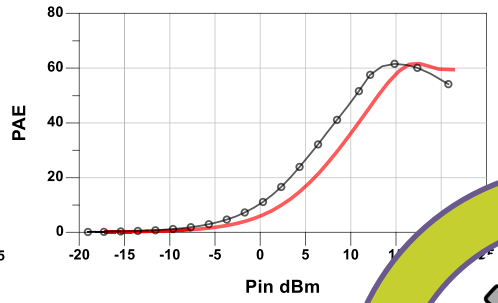
Large Signal model validation

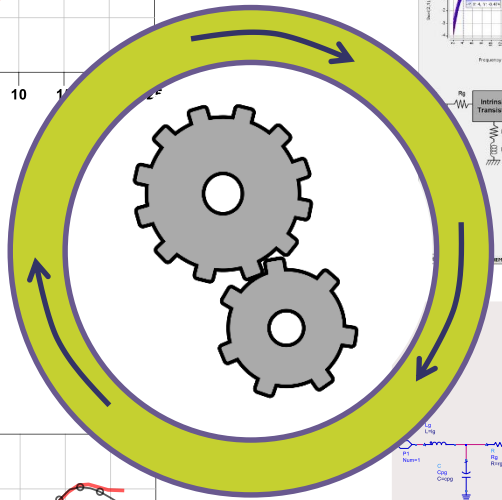
Empiric Load Pull measurements at the extrinsic planes



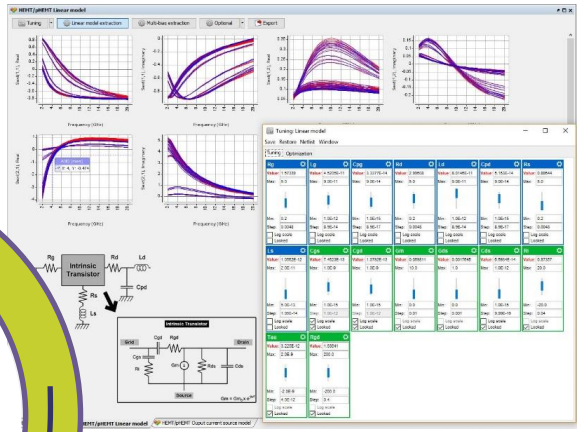
Application specific Load Pull Validation: ASM model

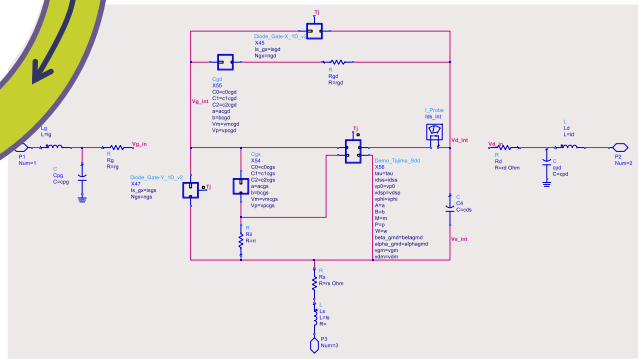


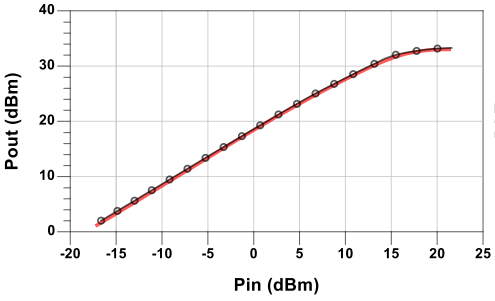


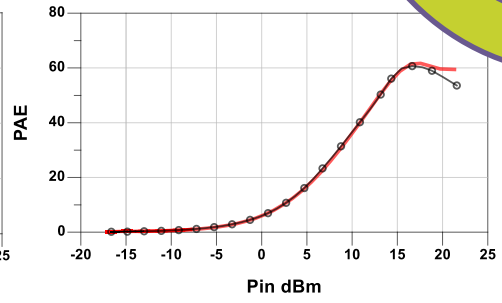


Modeling and validation flow









AMCAD Engineering
Advanced Modeling for Computer-Aided Design

Q&A

Thank you

Visit Booth # 328 for more!!!

Web Site: www.amcad-engineering.com

AMCAD Engineering
Advanced Modeling for Computer-Aided Design